Creating new worlds inside the computer

COS 116, Spring 2010

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Pseudocode

- Simple instructions: involve +, −, ×, ÷
- Compound instructions
  - Conditionals
  - Loops

- No need to sweat over exact wording during exams (unless it changes meaning!)

Discussion Time

Did you figure out how to express the selection sort algorithm in pseudocode?

```
Do for i= 1 to n-1
{
 find minimum element of the numbers in positions from i to n;

 swap that number with the i'th number;
}
```

Full pseudocode appears in Example 2 of Handout on pseudocode. (See “handouts” tab on course web page.)

"Algorithm" - definition revisited

"Pseudocode for turning a set of inputs into outputs in a finite amount of time"

Questions to think about:

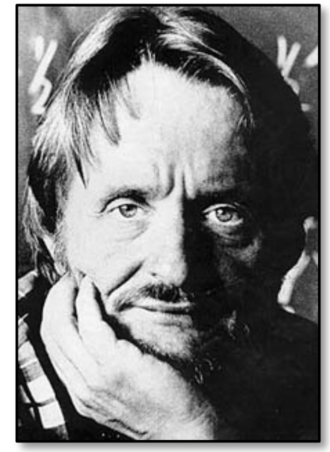
- What group of computational tasks can be solved by algorithms?
- How dependent is this group on the exact definition of pseudocode?

Today's topic:

Creating new worlds inside the computer.

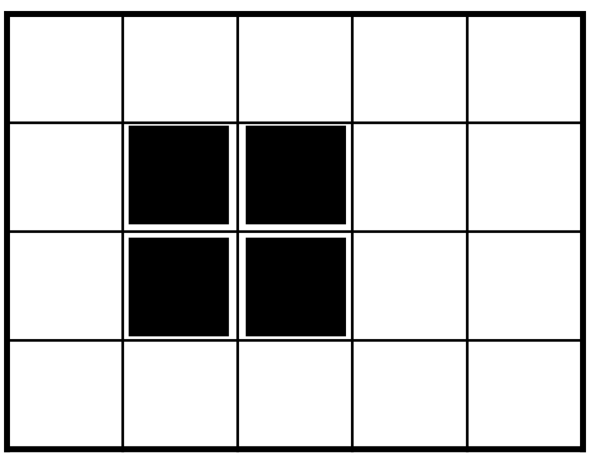
"simulation"

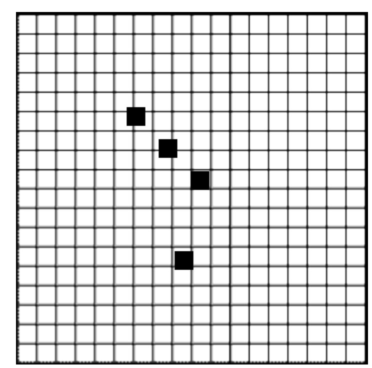
Conway's Game of life



- Rules: At each step, in each cell:
  - Survival: Critter survives if it has:
    2 or 3 neighbors.
  - Death: Critter dies if it has:
    1 or fewer neighbors, or more than 3.
  - Birth: New critter is born if cell is currently empty and
    3 neighboring cells have critters.

Example





Discussion Time

How would you write pseudocode that simulates Game of Life?

Should use: n x *n* array *A*
(for desired n)

A[i, j] = 1 means critter in square
A[i, j] = 0 means empty square

Q: How do we “traverse” such an array using the “loop” construct?
Q: How do we update such an array for the next time step?

Pseudocode for each step

```
Do for i = 1 to n
{
    Do for  j = 1 to n
    {
        neighbors ←
            A[i – 1, j - 1] + A[i – 1, j] + A[i – 1,j + 1] +
            A[i, j – 1] + A[i, j + 1] +
            A[i + 1, j – 1] + A[i + 1, j] + A[i + 1, j + 1]
        if ( A[I,j] = 1 AND neighbors = 2 ) then
                { B[i, j] ← 1 }
        else if (…)
                …etc. //see handout; Example 3//
    }
}
Do for i = 1 to n
{
    Do for  j = 1 to n
        { A[i,j] ←B[i,j] }
}
```

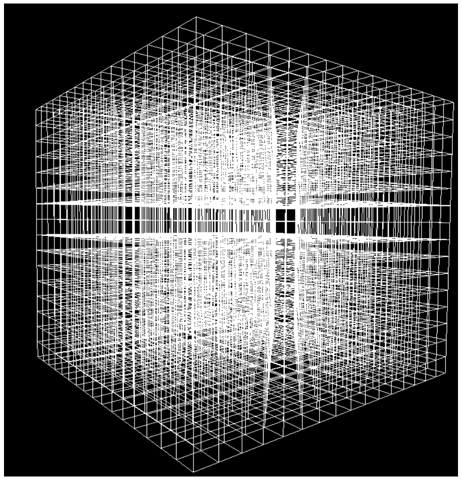
Lesson from the Game of Life?

- Simple local behavior can lead to complex global behavior

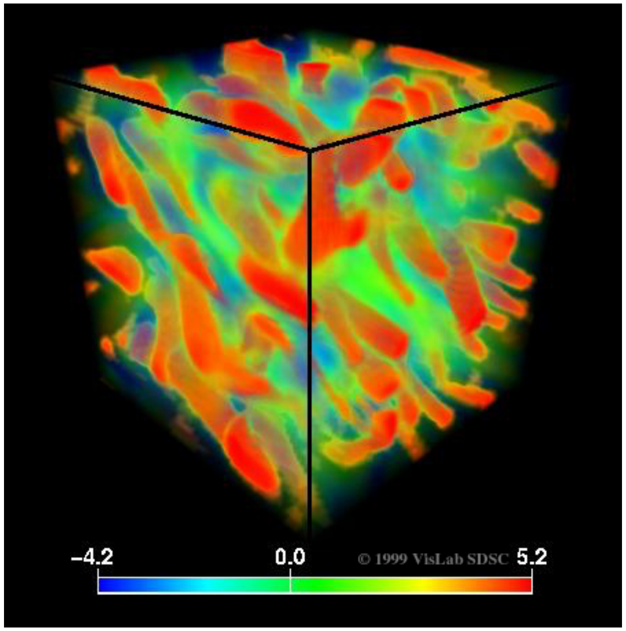
(See Brian Hayes article in readings.)

Next..

Twister simulation



- Divide region into 3D array
- Identify laws of physics for air



Navier Stokes equations:

How does a block of air move, given pressure, temperature and velocity differentials on boundary?

("differentials" = difference from neighbors)

Simulator pseudocode

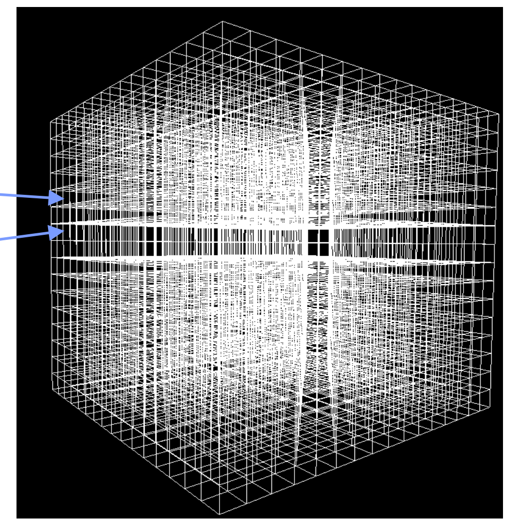
- Initialize Grid using data from observations: surface and aircraft measurements, radar (NEXRAD) readings, etc.

Do for *i* = 1 to *n*
{
    Do for *j* = 1 to *n*
    {
        Do for *k* = 1 to *n*
        { Update state of Grid[*i*, *j*, *k*] }
    }
}

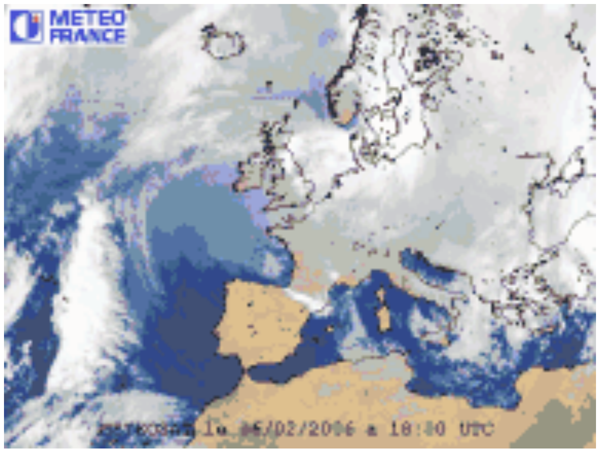
10ºC, 15 psi, 20% humidity

11ºC, 15 psi, 23% humidity

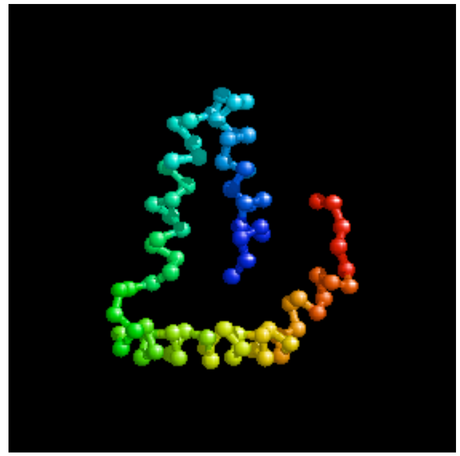
etc.



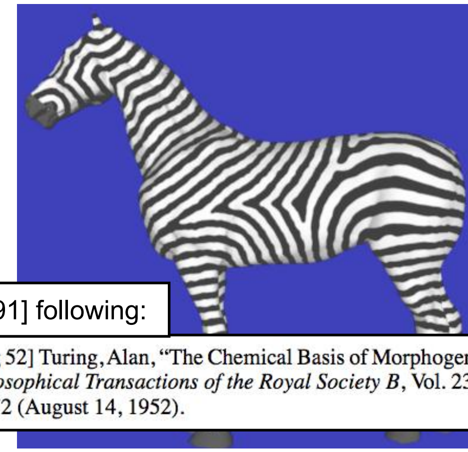
Other examples of simulation



Weather forecasting



Protein folding



[Turk 91] following:

[Turing 52] Turing, Alan, "The Chemical Basis of Morphogenesis," *Philosophical Transactions of the Royal Society B*, Vol. 237, pp. 37–72 (August 14, 1952).

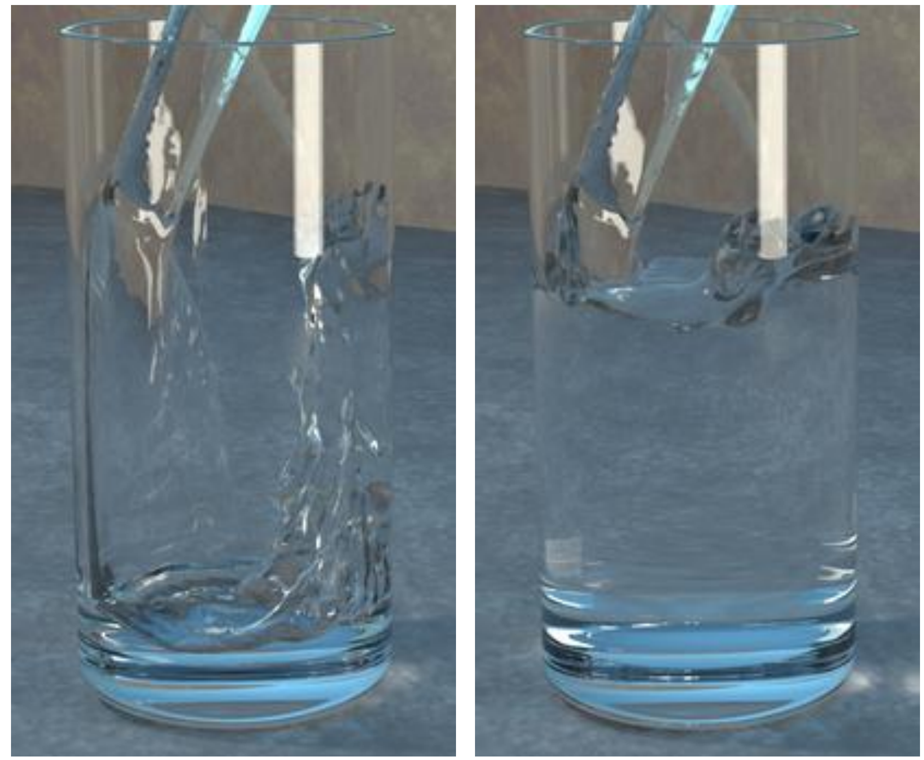
How patterns arise in plants and animals

Animation

Display

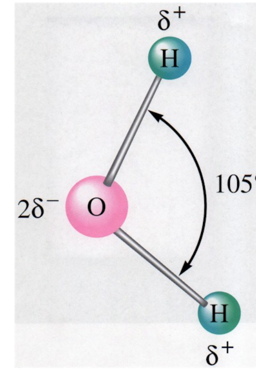
Q: How to display result of simulation?

A: Computer graphics (later in course)



[Enright and Fedkiw 02]

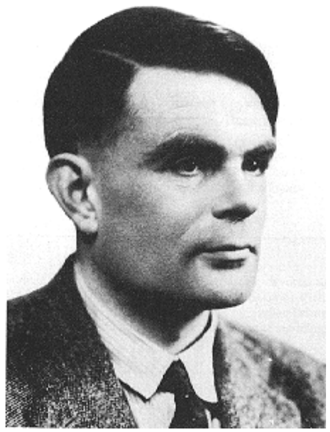
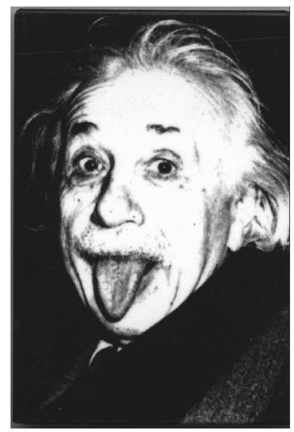
Physics of snow crystals



Water vapor $\xrightarrow{\text{cooling}}$ Water $\xrightarrow{\text{further cooling}}$ Snow crystals

- "Cooling" – reduce amount of molecular motion
- Crystal growth: capture of nearby floating molecules

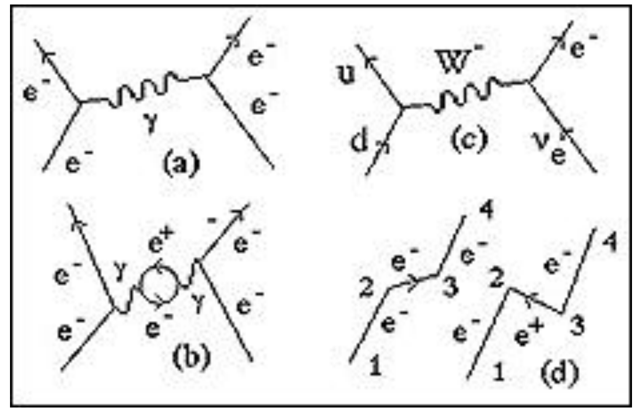
Bigger questions

Alan Turing   Albert Einstein

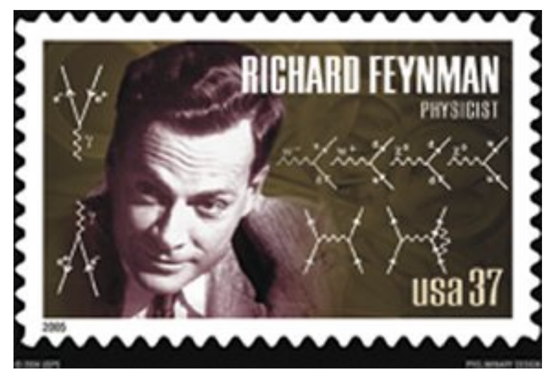
- Can computer simulation be replaced by a "theory of weather"? A "theory of tornadoes"?
- Is there a "theory" that answers this type of problem:
  - Given: A starting configuration in the game of life
  - Output: "Yes" if the cell at position (100, 100) is ever occupied, "No" otherwise

Actually, reverse trend: "theory of matter" (particle physics) is becoming computational.

1670 F = ma



Today



Hayes (reading this week):
The universe as a "cellular automaton"

Peeking ahead:

A computer can simulate another computer
(e.g., a Classic Mac simulator on a PC).
Will explore the implications of this in a future lecture.

Game of life is actually a “computer.”

Readings for this week: (i) Brian Hayes article; first 5 pages
(ii) Brooks 99-126
(iii) Conway’s game of life

HW 1 Due next Thurs.